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Lengthening temporalis myoplasty versus free muscle transfer with the gracilis flap for long-standing facial paralysis: A systematic review of outcomes

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INTRODUCTION

Long-standing facial paralysis has substantial functional, morphological, and psychological effects on the affected person. The lack of facial expression on the paralyzed side is not only an aesthetic issue but also a functional one, as the affected individual cannot communicate effectively, which may lead to social isolation. When managing facial paralysis, the primary interest focuses on reanimation of the smile and eyelid (Momeni et al., 2013). This review will focus on smile reanimation. The inability to smile is unfortunately not the only dynamic problem in the midface. The paralyzed side also remains static upon talking, which is equally embarrassing to the patients.

The main challenge of facial reanimation surgery is to provide symmetry at rest and with facial expressions. The current gold standard is revascularised and reinnervated free muscle transfer, mainly with a gracilis free muscle flap (Biglioli et al., 2013). Pedicled regional muscle flaps, such as temporalis muscle flaps, have received renewed interest. The indications for the 2 types of flaps are very similar, if not identical (Labbé and Bénateau, 2002). The gracilis flap can be innervated by either the contralateral facial nerve, masseteric nerve (the motor branch of the trigeminal nerve to the masseter muscle), or both (Ferreira and Marques, 2002; Manktelow et al., 2006; Biglioli et al., 2013). The different approaches have the same goal: providing symmetry at rest and with voluntary motion, oral competence, and a consistent spontaneous smile (a spontaneous smile can be “automatic,” such as upon greeting, or “emotional,” such as when listening to a funny story without being watched), as well as preventing synkinesis (Momeni et al., 2013). It is important to know the difference between a voluntary smile (a smile for which the patient has to actively think to produce a smile, such as upon smiling for a photograph), and a spontaneous smile, which can be both "automatic" and "emotional." The presence of an emotional spontaneous smile can be objectified only by seeing patients smile after letting them watch funny videos.

The aim of this article is to compare the outcomes of reconstruction of long-standing facial paralysis using either a gracilis free flap transfer or a lengthening temporalis myoplasty (LTM) according to Daniel Labbé. To accomplish this, we performed a systematic review of the available literature assessing outcomes of the 2 techniques.

MATERIAL AND METHODS

Surgical procedure

Gracilis free muscle transfer

The gracilis free muscle transfer for facial reanimation was first introduced by Harii et al. in 1976 (Ylä-Kotola et al., 2004; Terzis and Olivares, 2009; Faria et al., 2007). To achieve a spontaneous smile, the contralateral facial nerve was used to innervate the flap by using a cross-facial nerve graft (CFNG). This is considered the first choice by most authors, since reconstitution of both the automatic (upon greeting) and emotional smile (involuntary, e.g., when listening to a funny story) can be expected because of the stimulation by the contralateral facial nerve. The technique is usually performed in two stages: a first stage, during which the CFNG is created; and a second stage, during which the muscle is transplanted and the neurovascular anastomoses are performed. The second surgery is conducted when a positive Tinel sign is observed at the free end of the grafted nerve (Ylä-Kotola et al., 2004). Generally, the sural nerve is used (Ferreira and Marques, 2002). When the contralateral facial nerve is not available, or in patients with bilateral facial paralysis, the masseteric nerve is a good alternative. Initially, an “automatic” spontaneous smile was not expected with use of this nerve, but several authors found that some patients were able to achieve an “automatic” spontaneous smile over time with intensive smile training by a speech-language pathologist using mirror exercises, but the appearance of the “automatic” spontaneous smile was not consequent. This is due to cerebral plasticity (Manktelow et al., 2006; Nduka et al., 2012; Faria et al., 2007; Momeni et al., 2013). Although some results were contradictory (Terzis and Olivares, 2009), reinnervation of the gracilis muscle flap with the masseteric nerve became more and more popular because of its predictable results, rapid innervation, low donor site morbidity, and potential to achieve an “automatic” spontaneous smile through cerebral plasticity (Faria et al., 2007).

Some authors explored the possibility of combining the advantages of each technique through double innervation (Labbé and Huault, 2000; Cardenas-Mejia et al., 2015; Sforza et al., 2015). With this strategy, the masseteric nerve graft provides rapid reinnervation, thereby avoiding atrophy of the transplanted muscle and producing a strong contraction on voluntary smiling and “automatic” spontaneous smiling, whereas the CFNG facilitates both an “automatic” and “emotional” spontaneous smile (Faria et al., 2007).

Lengthening temporalis myoplasty

Lengthening temporalis myoplasty (LTM) was described by Daniel Labbé in 1997 as a modification of the temporalis myoplasty according to McLaughlin (1953). The advantage of Labbé’s technique is that use of a tendon graft is avoided, which provides better long-term results because there is no late stretching of the tendon. Recent studies describing the outcomes of LTM surgery found that an “automatic” spontaneous smile can be achieved in all patients, but it should be noted that an "automatic" spontaneous smile occurs seldom in some patients. This is remarkable and unexpected, as use of the masseteric nerve for reinnervation of the gracilis free muscle flap resulted in an "automatic" spontaneous smile in only two-thirds of patients (Labbé et al. 2012).

A significant disadvantage of the Gillies technique and its modifications is that temporal hollowing occurs as a result of muscle harvesting, thus exaggerating facial asymmetry. LTM according to Labbé avoids temporal hollowing by 2 maneuvers: preserving the superficial temporal fat pad, and dissecting just above the deep temporal fascia. The muscle should be released from the temporal fossa with care for the neurovascular pedicle.

When using the LTM technique, preoperative determination of the key-points is extremely important in order to achieve a smile as symmetrical as possible. The key-points are placed in the plane of the mimic muscles and are reached by subcutaneous dissection medial to the nasolabial fold incision. During the procedure, the tendon, which is still attached to the coronoid process, is accessed via a nasolabial fold incision. It is then stripped from the coronoid process, while ensuring that as many fibers as possible are preserved. The tendon is subsequently stretched to the length of the nasolabial incision. The anterior and longest part of the tendon will be attached at the alar base and will correct the nasal scoliosis. The shortest part will be sutured at the commissure and create symmetry at rest. Then, the 3 key-points are attached to the tendon.

Literature search and data extraction

Search strategy and results

The literature search was performed using several databases: PubMed, Web of Science, Wiley Online Library, Cochrane Library, Directory of Open Access Journals, and SAGE Premier 2011 database. In PubMed, the search strategy consisted of the MeSH term “facial paralysis” AND free text words “temporalis lengthening myoplasty” OR “myoplastie d’allongement” OR “Labbe” OR “facial reanimation” OR “pedicled regional muscle flaps” OR “free muscle flaps” OR “gracilis muscle transfer” OR gracilis free muscle flap” OR “gracilis flap.” The search strategy was adapted for the other databases, using these free text words: “facial paralysis” AND “facial reanimation” AND “temporalis” OR “gracilis.”

Study selection criteria

No articles were excluded on the basis of language. The inclusion criteria were as follows: (1) studies involving patients with longstanding facial paralysis; (2) studies involving patients who underwent facial reanimation with gracilis free muscle flap transfer or LTM according to Labbé; (3) randomized controlled trials (RCTs), controlled clinical trials (CCTs), or case series with a sample size greater than 5. The exclusion criteria were studies with a level of evidence rated as V or studies involving patients who had undergone irradiation.

Data extraction

Data were extracted from each of the included studies by a single investigator. The extracted data were as follows: number of patients, sex and age of the patients, cause of the facial paralysis, the surgical treatment used to reanimate the smile and the time between the 2 stages (if applicable), mean period until movement and follow-up time, complications, outcome evaluation systems, commissural displacement, and spontaneity of the smile.

RESULTS

Studies retrieved and included

A total of 469 articles were retrieved through our PubMed search. The number of articles retrieved via the other databases were as follows: Web of Science, 144; Wiley Online Library, 177; Cochrane Library, 2; Directory of Open Access Journals, 7; and SAGE Premier 2011 database, 0. Sixteen studies met the inclusion criteria, all of which were retrospective case series. No RCTs or CCTs that fulfilled the inclusion criteria were found.

Patient number and characteristics

The total number of patients included in this review was 920. The sample size of each included study ranged between 4 and 505. The age range varied between 3 and 75 years old. An overview of the patients in the included studies is shown in Table 1.

Evaluation systems

Most of the included studies used subjective evaluations by the patient, surgeon, and/or observer(s) to assess the surgical outcomes (Labbé and Huault, 2000; Ferreira and Marques, 2002; Faria et al., 2007; Hayashi et al., 2015; Veyssiere et al., 2015, Bae et al. 2006). Ylä-Kotola et al. (2004) used the scale described by House-Brackmann, which is a well-known scale that is also based on subjective findings. The most commonly used validated scale was the Terzis Functional and Aesthetic Grading System for Smile, initially described by Terzis and Olivares (Terzis and Olivares, 2009; Biglioli et al., 2012a; Cardenas-Mejia et al., 2015). Gousheh et al. (2011) objectively measured commissural displacement, and the quantitative results were used to classify the patients into 4 outcome groups (Table 6). Other studies assessed the results by just measuring the extent of commissural displacement and/or angle (Manktelow et al., 2006; Hontanilla et al., 2011; Gousheh et al., 2011). The remaining assessment scales were digital systems developed to systematically measure commissural displacement: FaceMS (Bianchi et al., 2010), FACE-Gram (Bhama et al., 2014), and the SMART system (Sforza et al., 2015). Questionnaires were also performed to evaluate patient satisfaction and spontaneous (in most studies an “automatic” smile was enough be considered as spontaneous) smiling rates (Ferreira and Marques, 2002; Ylä-Kotola et al., 2004; Manktelow et al., 2006; Bianchi et al., 2010). Quantity of smiling (percentages of contralateral smiling or millimetric measurements) are just 1 way to look at the matter: the “quality” of smiling, the ability to communicate expressions, and other “nonpalpable” aspects of facial expressions are far to be re-established.

Surgical interventions for facial reanimation

Most of the included studies described cases of facial reanimation with a gracilis free muscle transfer, innervated by a CFNG (Ferreira and Marques de Faria, 2002; Ylä-Kotola et al., 2004; Bae et al., 2006; Faria et al., 2007; Terzis and Olivares, 2009; Bianchi et al., 2010; Gousheh et al., 2011; Hontanilla et al., 2013; Bhama et al., 2014), a masseteric nerve graft (Bae et al., 2006; Manktelow et al., 2006; Bianchi et al., 2010; Faria et al., 2007; Hontanilla et al., 2013; Bhama et al., 2014), or double innervation with both cross-facial and masseteric nerve grafts (Biglioli et al., 2012; Cardenas-Mejia et al., 2015; Sforza et al., 2015). Some studies compared innervation with the cross-facial or masseteric nerve (Bae et al., 2006; Bianchi et al., 2010 Faria et al., 2007; Hontanilla et al., 2013; Bhama et al., 2014). Other studies assessed the outcome of facial reanimation surgery after LTM (Labbé and Huault, 2000; Gousheh et al., 2011; Hayashi et al., 2015; Veyssiere et al., 2015). Gousheh et al. (2011) compared LTM to gracilis flap using a CFNG.

Outcomes

In the included studies, efficacy outcomes were analyzed by assessing mouth symmetry both at rest and upon smiling, as well as the quality of the smile. Many different evaluation systems were used. Table 3 provides an overview of the outcomes and evaluation systems used in all studies included in this review.

Gracilis free muscle transfer

Gracilis free muscle transfer with cross-facial nerve graft

Ferreira and Marques de Faria (2002) reported their results of 26 patients treated with a gracilis free muscle flap innervated by a CFNG. Symmetry at rest, quality of a voluntary and an "automatic" spontaneous smile, and overall aesthetics of the midface were evaluated subjectively by the surgeon, the patient, and an observer by watching a video and images of the preoperative and 1-year postoperative results. Improvement was rated as excellent in 77%, 84.5%, and 61% of the patients, based on assessments by the patient, surgeon, and observer, respectively. Objective improvement was also noted, as an increase in the angle formed by the midline and the line extending between both corners of the mouth. This angle, which is approximately 90° at rest in normal faces, is reduced in patients with facial paralysis. The angle improvement after surgery was more obvious during movement than at rest. The quality of life, assessed by the facial disability index described by Van Swearingen and Brach (1996), also improved. Of the 2 subscales included in this index, the physical function scale (which relates to lip function) increased from 58.5 preoperatively to 86.5 postoperatively, and the social/well-being scale rose from 69.2 preoperatively to 85.0 postoperatively.

Ylä-Kotol et al. (2004) performed a long-term clinical evaluation of 11 patients treated with gracilis flap innervated by a CFNG. Quality of life (assessed by patient interviews) improved in approximately 78% of patients postoperatively. Video recordings were also obtained, including images at rest, while speaking, and during voluntary movements to show mimic muscle function. Functional outcome was rated according to the scale described by House-Brackmann, with higher grades representing more facial dysfunction. Almost two-thirds of patients were rated as grade 2 to 3, one-third as grade 4, and one-tenth as grade 5. The longer the follow-up time after surgery, the worse the muscle function.

Terzis and Olivares (2009) evaluated 10 patients relevant to this review. Assessments included electromyography (EMG) and videos (preoperatively, 2 years postoperatively, and at last follow-up). The quantity of motor units on EMG was maintained over time. Four observers determined outcomes using the Terzis' Facial Grading System (Table 4) and evaluated whether the smile weakened over time. Outcomes were rated as good or excellent in over 70% of patients, and the length of follow-up did not seem to affect the results.

Gracilis free muscle transfer with masseteric nerve

In a study of 27 patients reported by Manktelow et al. (2006), 45 muscle transplantations were performed (most patients had bilateral paralysis). In 19 patients (31 transplantations), FaceMS was used postoperatively to assess the amount and direction of commissure and mid upper lip movement. (Tomat and Manktelow, 2005) This validated technique requires the use of a video camera, video editing program, and Adobe Photoshop. During the technique, a transparent ruler is held against the lips in a standardized manner, and the mid upper lip point is considered to be the point on the vermillion margin of the lip halfway between the commissure and the central point of Cupid's bow. The 8 patients who were not assessed by FaceMS were evaluated by standard photographs or videos. All patients completed a questionnaire to assess aesthetic quality, use and control of the reconstructed smile, functional effects (on eating, drinking, and speech), and smile spontaneity ("automatic").

In the study, all flaps survived and all muscles developed movement. Based on FaceMS results, the mean commissure movement was 13 mm ± 4.7 mm, with an angle of 47° ± 15° above the horizontal line. The average mid upper lip movement was 8.3 mm ± 3 mm at an angle of 42° ± 17°. In patients with unilateral reconstruction, the amount of movement of the commissure on the reconstructed side was 85% of that on the healthy side, and mid upper lip movement was significantly lower (68%) than that on the normal side. The direction of movement (angle) of the commissure and mid upper lip were not significantly different on the reconstructive and normal sides. Movement was somewhat greater in males than in females, although the difference was not statistically significant. This may be explained by the higher muscle weight of the grafts in men. Older and younger patients had similar commissure movement. Only 4 of the 31 muscles from which data were available had a commissure movement less than normal (it was 6 mm in all 4 muscles, whereas the lower the limit of normal is 7 mm). These muscle flaps were transplanted in 2 patients with Moebius syndrome.

The questionnaire results revealed that after surgery, 89% of patients had an "automatic" spontaneous smile: 59% reported spontaneous smiling routinely, and 37% reported spontaneous smiling all of the time. Overall, 85% learned to smile without biting, with 69% accomplishing this most of the time and 15% needing to bite to produce a smile at least half of the time. Postoperatively, 30% of the patients were uncomfortable during eating because of a smile occurring while chewing. Overall, 50% of patients reported an improvement in eating and drinking after surgery, whereas 38% reported no significant difference. Speech improved in 52% of patients postoperatively.

Bae et al. (2006) published a comparative retrospective study involving children, in which gracilis muscle transplantation innervated with a CFNG was compared to innervation by the ipsilateral masseteric nerve. Measurements were conducted by third-party assessors both pre- and postoperatively. The results of improvements in commissural excursion were summarized (Table 3). The group with the CFNG had significantly less commissural movement on the operated side than on the normal side. The group who underwent surgery involving the masseteric nerve all had bilateral paralysis. There were no significant differences between sides in this group, but commissure movement was greater than in the CFNG group. Commissure movement in the masseteric nerve group and the normal side of the CFNG group were similar.

In their retrospective case study, Faria et al. (2007) compared the outcomes of patients operated by the 2-stage technique with a CFNG graft (group 1, n = 58) versus the outcomes of those who underwent a 1-stage technique with the masseteric nerve (group 2, n = 22). All patients underwent pre- and postoperative photography and videography to assess facial movements, including while laughing. The reconstructed smile was evaluated by the surgical team using a nonvalidated grading system based on shape and intensity (Table 6). In all, the results of 53.4% of patients in group 1 and 86.3% in group 2 were rated as good or excellent. In group 1 patients, the mean age was significantly lower in patients with good or excellent results compared to those with fair/poor or worse results. Spontaneous “automatic” smiles were achieved by 34% of patients in group 1 and 0% in group 2. This is a poor result compared to other studies.

Bianchi et al. (2010) conducted a retrospective case study of 15 patients, 8 of whom were re-innervated using the masseteric nerve and 7 with a CFNG. A speech-language pathologist trained all patients using mirror exercises and biofeedback. Assessments included standardized neurological examination, an EMG, clinical evaluations (of speech, oral continence, and facial expressions), photographs and videos (analyzed according to Manktelow et al. (2006), as previously described), and a questionnaire (to evaluate improvement in oral competence and facial symmetry, at rest and upon smiling). Symmetry was rated as excellent or good in all cases. All patients who underwent reinnervation with the masseteric nerve were satisfied with their aesthetic and functional results. Reinnervation occurred later in adults (5−6 months) than in children (3.5 months).

In 2013, Hontanilla et al. reported the results of their retrospective study comparing gracilis flap innervation methods: in group 1 (n = 20), innervation was by a CFNG; in group 2 (n = 27), innervation was by a masseter nerve graft. The authors used the FACIAL CLIMA system, which is an optical system that measures facial movements by following reflecting dots on the patient's face. Videos are recorded with 3 infrared light cameras while the patient smiles, closes the eyes, elevates the forehead, and puckers the mouth. Software measures and analyses vectors during these 4 movements, then processes the images automatically and gives 3-dimensional information on velocities, angles, and distances. Outcomes were assessed 24 months postoperatively.

In group 1, the mean postoperative oral commissure displacement was 8.4 ± 3.1 mm on the healthy side and 5.1 ± 2.6 mm on the reconstructed side (p = 0.001), and the mean postoperative commissural contraction velocity was 33.3 ± 11.9 mm/s on the healthy side versus 23.8 ± 12.8 mm/s on the reconstructed side (p = 0.014). In group 2, the mean postoperative oral commissure displacement was 9.1 ± 3.4 mm on the healthy side and 7.7 ± 2.8 mm on the reconstructed side (p = 0.41), and the mean postoperative commissural contraction velocity was 35.4 ± 13.8 mm/s on the healthy side versus 31.3 ± 15.1 mm/s on the reconstructed side (p = 0.67). For both parameters, the percentage of recovery compared to the normal side was higher in group 2, although statistical significance was achieved only for commissure displacement (61.1% versus 90.6%; $p = 0.042$).

In Bhama et al.'s (2014) retrospective study of 78 patients, gracilis muscle flaps innervated with a CFNG were compared to flaps innervated by the masseteric nerve. The authors developed FACE-Gram, a software tool for objectively measuring facial landmarks on photographs and videos. On average, smile excursion on the healthy side decreased from 8.4 mm preoperatively to 7.2 mm after surgery, whereas excursion on the affected side increased from −0.86 mm preoperatively to 7.8 mm. Angle excursion also decreased on the healthy side and increased on the affected side. Symmetry at rest and upon smiling improved after surgery. The details can be found in Table 2. Flaps innervated by the masseteric nerve had a mean of 2.2-mm greater excursion than those innervated by a CFNG; however, flaps with a CFNG showed better symmetry upon smiling.

Gracilis free muscle transfer with double innervation

Double innervation can be performed as a single-stage or 2-stage procedure Cardenas-Mejia et al. (2015) reported a clinical series of 9 patients using a gracilis free muscle transfer flap with double innervation: CFNG in the first stage, and a second stage during which the muscle was transplanted and masseteric nerve was coapted end-to-end to the CFNG. All patients were evaluated pre- and postoperatively using electrophysiological studies and videos, and graded according to the Terzis and Noah grading system (Table 4) by 4 separate judges. Preoperatively, 7 patients were grade 1 and 2 patients were grade 2. After reanimation surgery, the grades improved significantly ($p < 0.0001$), resulting in 1 patient being rated as grade 3, 4 patients as grade 4, and 4 patients as grade 5. The postoperative EMG findings showed very good outcomes, with a mean lapse time of 4.14 milliseconds and mean motor recruitment of 68.33%. A significant linear relation was found between reinnervation time and age: the time was longer in older patients. Patients with a shorter reinnervation time had a higher smile grade postoperatively.

In 2015, Sforza et al. reported the results of 13 patients evaluated clinically and by motion analysis before and at least 11 months after gracilis flap with double innervation surgery. Nine high definition cameras filmed the patients while they performed 5 repetitions of a series of 3 facial expressions (smile without biting = “automatic” spontaneous smile, smile with biting = voluntary smile, and spontaneous smile evoked by watching funny videos = “emotional” spontaneous smile). Using the SMART system, an optoelectronic 3-dimensional (3D) motion analyzer at 60 Hz captured the facial movements, and software identified 2-dimensional (2D) and 3D coordinates of 11 markers taped on facial landmarks. Total labial mobility was calculated as the sum of the displacement of the markers. To assess symmetry, 2 indexes were calculated: ratio of the paretic to healthy side (activation ratio), and percentage ratio between the difference and sum of the healthy/paretic displacements (asymmetry index). The mean total displacement of the healthy and paretic sides (3D analysis), lateral displacement (2D analysis), ratios, and asymmetry indexes were calculated.

The surgery had a 15.38% failure rate; 2 patients failed to recover any function. During the preoperative maximal smiles, the average 3D mobility of the paralyzed side was lower than on the normal side, the activation ratio was 52%, and the asymmetry index was greater than 30%. Postoperatively, there was a significant decrease in side differences, with the activation ratio ranging between 75% (without biting) and 91%

(with biting), and asymmetry index being less than 20%. The activity ratio and asymmetry index exhibited significant differences when smiling with biting, which were due to both reduced healthy-side motion and increased reanimated-side motion. Similar results were seen with both “automatic” and “emotional” spontaneous smiles. Postoperatively, the labial commissure moved toward the reanimated side in all patients upon smiling, whereas the philtrum moved to this side in only about one-half of the patients.

Biglioli et al. (2012b) evaluated patients who underwent a gracilis free muscle flap with single-stage double innervation. All patients began biological biofeedback training when muscle contraction became evident. Overall outcomes were assessed using the Terzis and Noah system (Table 4), and “emotional” spontaneous smiling was evaluated by 4 different observers who viewed video recordings of the patients watching funny videos. All flaps survived. The outcomes were graded as excellent in 50% of patients, good in 33%, and moderate in 17%. Those patients with an excellent grade achieved a symmetrical smile with a complete gracilis contraction. All patients achieved an “emotional” spontaneous smile. The quality of spontaneous smiles was slightly inferior to that of voluntary smiles.

Lengthening temporalis myoplasty according to Labbé

Four studies assessed outcomes after reanimation surgery via LTM. Labbé and Huault (2000) described the outcomes of LTM in 10 patients. A third party performed the outcome assessments. Both static and dynamic symmetry were taken into account and the outcomes were rated as poor, average, good, or excellent. The postoperative outcomes were excellent in 6 patients (60%).

In 2015, Hayashi et al. reported their experience with LTM in 5 patients. The patients self-evaluated the outcome by taking into account their general impression, static appearance, overall symmetry, cheek movement, and smile. The first patient developed a dimple in the nasolabial fold and, after correction, was highly satisfied with the results. The second patient had effective static symmetry and lip movement immediately after surgery and good smile expression and symmetrical lower lip shape when opening the mouth 2 months postoperatively. Four patients had reduced mouth opening after surgery, which resolved with training. Two patients developed dimple formation at the tendon insertion site, which required minor revision surgery. The most serious complication was a salivary fistula, producing a subcutaneous fluid collection. An opening was made in the nasolabial scar for fluid drainage, which resolved this complication after 4 months.

Veyssiere et al. (2015) evaluated the results of smile reconstruction with LTM in 34 patients. All patients began speech therapy 3 weeks postoperatively, and 12 underwent electrostimulation. Various additional procedures were performed during the reanimation surgery to improve the results. Assessment was subjective and performed by the patient and medical team. A spontaneous, “automatic” smile was achieved in 32 patients (94%), after a mean of 8.7 months. Of the 2 patients who did not achieve smile spontaneity, 1 patient was a 37-year-old who developed disinsertion of the tendon at the nasolabial fold. Reinsertion was unsuccessful. The other patient had bilateral facial paralysis and mental retardation. This high percentage of “automatic” smile spontaneity after TLM has not been observed in centers other than that of Labbé.

Gousheh et al. (2011) conducted a retrospective study, which included 509 patients of relevance to this review: 505 underwent free muscle flap surgery and 4 underwent LTM according to Labbé. All patients started rehabilitation with light massage and electrostimulation 2 months postoperatively. After the first movements appeared, patients were encouraged to perform facial expression exercises in front of the mirror. In patients who underwent LTM, these exercises were started earlier. A simple objective classification was used to assess surgical outcomes (Table 7). Of those patients who underwent muscle flap surgery, 71 (14%) achieved excellent results, 385 (76%) attained good results, 40 (8%) attained satisfactory results, and 10 (2%) had a "bad recovery." The 4 patients who underwent LTM achieved satisfactory results.

Summary of subjective evaluations

Many studies included in this review assessed surgical outcomes using a subjective scale. Rates of excellent or good results after a gracilis graft with CFNG were 84.5% (Ferreira and Marquis, 2002), 53.4% (Faria et al., 2007), 70% (Terzis and Olivares, 2009), and 100% (Bianchi et al., 2010). Similarly, Gousheh et al. (2011) reported excellent results in 14% of patients and good results in 76%. In studies involving gracilis flaps innervated with the masseteric nerve, outcomes were rated as good or excellent in 86.3% patients (Faria et al., 2007) and 100% of patients (Biachi et al., 2010). Studies of double innervation reporting good or excellent results in 89% (Cardenas-Mejia et al., 2015) and 84% of patients. (Biglioli et al., 2012b) In studies involving LTM, Labbé and Huault (2000) reported up to 60% of patients with excellent results, whereas Gousheh et al. (2011) reported only satisfactory outcomes. Overall, these studies indicated that the best and most consistent results were found in patients receiving gracilis muscle flaps reinnervated using the masseteric nerve or double innervation. The results for LTM were contradictory, but this may be attributed to the small number of patients and lack of surgical experience with the technique in the Gousheh et al. (2011) study.

Summary of commissural displacement results

In studies reporting objective quantifiable data, the mean postoperative commissural excursion results of patients who received a gracilis flap reinnervated by the masseteric nerve were as follows: 13 mm (Manktelow et al., 2006), 13.8 mm (standard deviation [SD], 4.19) (Bae et al., 2006), 7.7 mm (SD, 2.8) (Hontanilla et al., 2013), and 6.5 mm (Bhama et al., 2014). Some of these studies compared the mean commissural displacement of these patients with another group of patients who underwent surgery by the same team but with CFNG reinnervation. The mean excursion in these other groups was 7.9 mm (SD 4.19) (Bae et al., 2006), 5.1 mm (SD 2.6) (Hontanilla et al., 2013), and 6.5 mm (Bhama et al., 2014). In Sforza et al.'s (2015) study of patients who underwent double innervation, the ratio of commissural excursion of the paretic side to healthy side improved from 52.18% preoperatively to 74.95% postoperatively. In all comparative studies, commissural displacement was greater after surgery involving masseteric nerve reinnervation than a cross-facial nerve graft reinnervation. Patients with double innervation had similar results to those who had surgery involving masseteric nerve reinnervation, although they demonstrated a stronger voluntary smile and more symmetrical (albeit weaker) "automatic" and "emotional" spontaneous smile.

Summary of smile spontaneity outcomes

When we evaluated situations in which cerebral plasticity was required to achieve a spontaneous smile (gracilis flap innervated with the masseteric nerve and LTM), substantial differences were observed between studies. For gracilis flap with masseteric reinnervation, spontaneous smiles were reported in 0% of patients in Faria et al.'s study (2007), whereas Manktelow et al. (2006) noted an 89% spontaneous smiling rate. Furthermore, Biglioli et al. (2012b) achieved "emotional" spontaneous smiles in 100% of their patients. Although this was due to double innervation, these authors observed a difference in smile quality according to its origin: voluntary smiles had larger commissural excursion than spontaneous smiles. In studies of LTM, up to 94% of patients achieved "automatic" spontaneous smiles in Veyssiere et al.'s (2015) study, whereas Gousheh et al. (2011) reported that none of their patients achieved a spontaneous smile. Differences in experience with the technique and physiotherapy programs might have contributed to these discrepant findings.

DISCUSSION

Over the years, different methods have been proposed to treat long-standing facial paralysis. The concept of free muscle flaps was first introduced by Harii et al. in 1976 and has been subsequently refined numerous times. Currently, free muscle flaps are the gold standard for facial reanimation. Many muscles have been used, but the gracilis remains the most popular free muscle flap. Each surgeon has his or her own preference, and a consensus has not been reached regarding the most appropriate flap. Another area of discussion involves the choice of nerve to innervate the muscle graft. CFNGs, first described by O'Brien in 1980 (Veyssière et al., 2015), have the advantage of achieving a spontaneous (both "automatic" and "emotional") and coordinated smile. (Faria et al., 2007; Terzis and Olivares, 2009) However, there are disadvantages to this technique, including the need for 2 operations. Although a 1-stage procedure has been described and an increasing number of authors support its use, results with this method are sometimes contradictory (Terzis and Olivares, 2009), and most authors continue to prefer the 2-stage approach. Leaving the transplant denervated while waiting for axons to grow results in atrophy of the muscle flap. Another disadvantage is the need for a nerve graft, which causes additional morbidity (although it is well tolerated by most patients). The technique also results in 2 sites of coaptation, which results in a greater likelihood of axonal loss and thus often a weaker smile. Asymmetry of the reconstructed smile may develop as well. (Hontanilla et al., 2013)

In this systematic review, we have attempted to examine the effectiveness of each surgical technique. A major difficulty with examining the outcomes of each surgical technique is the many different ways in which surgical results were evaluated. Some studies used no quantifiable methods of efficacy assessment. Others used patient, surgeon, or observer surveys to evaluate the outcomes. These types of surveys are subject to the possibility of self-serving bias. Almost all patients included in studies of LTM were evaluated by subjective methods, and very little quantifiable data were available regarding LTM. The total number of patients who underwent LTM was also much lower than those who underwent gracilis muscle flap surgery (53 versus 867 patients).

In many studies, smile excursion was greater in gracilis flaps innervated by the masseteric nerve (Bae et al., 2006; Bianchi et al. 2010; Hontanilla et al., 2013; Bhama et al., 2014). The greater axon count and throughput of axons into the obturator nerve, compared to the CFNG, results in an increased smile excursion (Bhama et al., 2014). The healthy side is also left untouched, so complications such as scar contraction are avoided. A disadvantage of masseteric neurotisation is the possibility of synkinetic movements of the reconstructed side while chewing. Patients generally do not complain greatly about this, and it usually disappears within a few months (Hontanilla et al., 2013). Patients can train themselves to dissociate commissural displacement and chewing movements, which are both triggered by the trigeminal nerve. Using the masseter nerve for reinnervation produces movement that is closer to the normal range, and the results are more consistent than those achieved with CFNGs.

The role of the masseteric nerve in unilateral paralysis might be greater than previously thought. Candidates considered for CFNG innervation may benefit from masseter nerve innervation instead. A masseteric nerve graft may be particularly useful for older patients, patients with major asymmetry at rest, or patients who want to avoid 2 operations. Clinical experience has shown that both “automatic” and “emotional” spontaneous smiles can be achieved with the masseteric nerve, refuting previous scepticism (Manktelow et al., 2006; Bianchi et al., 2010). However, in the literature, most authors do not make the difference between an “automatic” and an “emotional” smile. Therefore it is not easy to compare the real spontaneity of the smiles in some of the included studies. An “emotional” smile can be objectified only by filming patients watching funny movies. Authors of the studies that did this reported reported a much lower rate of “emotional” smiles then automatic smiles. This shows that cerebral plasticity occurs indeed and can make patients smile “emotionally,” but this happens much less with trigeminal input than with cross-facial input. Some patients were able to achieve a symmetrical smile on command but exhibited asymmetry when spontaneously laughing (Faria et al., 2007). The necessity for long-term training requires cooperation from the patient. The goals of reanimation surgery are not only to limit functional handicap but also to regain facial expression as much as possible by aiming for static symmetry, as well as dynamic symmetry during emotional triggers.

Many authors focus on the quality of the smile, but an “emotional” spontaneous smile is much more intense and pleasant than a voluntary smile evoked through biting, or an “automatic” spontaneous smile, even if the smile is aesthetically less pleasing.

This should be taken into account. Double innervation has been proposed in an attempt to combine the advantages of 2 nerves. By using both a masseteric nerve graft and CFNG, spontaneous smiles were achieved and patients could smile voluntarily by biting (Biglioli et al., 2012; Cardenas-Mejia et al., 2015; Sforza et al., 2015). The spontaneous smile with double innervation is usually a bit less intense than the voluntary smile, but still better than after CFNG alone. The number of axons passing through a CFNG is small, which likely explains its moderate results. By combining the 2 nerves, good innervation of the gracilis graft is provided by the masseteric nerve. It has been proposed that spontaneous smiles are better quality with dual innervation because the limited number of CFNG axons trigger a portion of the masseteric nerve axons, thereby resulting in a bigger lip excursion. However, this mechanism has not been firmly established, and instances of failure have also been reported (Sforza et al., 2015). An “emotional” spontaneous smile with double innervation reanimation surgery is thus less strong than an “automatic” spontaneous smile achieved with single masseteric nerve reinnervation, but is still stronger than a spontaneous smile triggered by a single CFNG. We conclude that the best spontaneous smile can be achieved with reinnervation by the masseter nerve, but that double innervation is a safer option in case cerebral plasticity fails, and also higher rates of “emotional” spontaneous smiles are reached through CFNG input. As most authors note no difference between the “automatic” and the “emotional” spontaneous smile, it is difficult to completely ignore the benefit of the CFNG, even if the results of symmetry are less. Patients report the big impact of the pleasure that they have smiling “emotionally.”

Labbé introduced the modified LTM procedure in 1997. This technique, as previously described, moves the whole temporal muscle antero-inferiorly and inserts its tendon into the perioral muscles in the nasolabial fold. The muscle flap is regional and thus pedicled and innervated. This overcomes all the difficulties with re-innervation of free muscle flaps. The technique immediately affects the shape and movement of the nasolabial fold. Static improvement immediately after surgery and early reanimation are achieved. Because of these advantages, LTM has gained increasing attention worldwide, although it remains considerably less common than free muscle flaps. A remarkable finding was that almost all patients obtained an “automatic” spontaneous smile, compared to the results of the masseter nerve grafts with gracilis free muscle flaps, in which approximately two-thirds of patients achieved a spontaneous smile. This finding is unexpected, because the mechanism of achieving a spontaneous smile, namely, cerebral plasticity, is the same in both procedures. The use of different kinds of postoperative speech therapy may have contributed to these findings. Because of its advantages, including excellent aesthetic results and low donor site morbidity, LTM is a superb alternative to gracilis free muscle transfer. (Veyssière et al., 2015)

Nevertheless, ensuring that the fascia of the temporalis muscle tendon reaches the nasolabial fold and performing an osteotomy of the coronoid process and zygomatic arch may seem complicated and invasive. This causes many surgeons to be hesitant to use this technique, although the procedure is fairly simple for a skilled surgeon with good knowledge of the local anatomy (Hayashi et al., 2015). A few articles included in this review, other than those published by Labbé himself, reported a limited number of clinical cases involving LTM; their results were rather mediocre. Gousheh et al. (2011) achieved only satisfactory results with LTM, which may be because of the investigators’ very limited experience with the procedure. Facial reanimation surgery has a long learning curve, and experience is necessary to achieve good results. Surgical teams all over the world have reported significant improvement in outcomes over time, no matter what technique is used. Because of its mediocre results and also because of its facial incisions, many surgeons do not consider LTM an option except for older people who are not good candidates for free muscle transfer or for people who desire less extensive surgery (Hontanilla et al., 2013). Table 8 gives an overview of the characteristics of each technique.

One of the most commonly used outcome assessment scales for facial paralysis in the literature is the House-Brackmann scale; however, few studies in this review used the scale. The main drawbacks of this scale are that it is observer-dependent and it assesses facial paralysis in qualitative terms (Hontanilla et al., 2013). The wide variety of outcome variables in the selected publications posed substantial restrictions in the current systematic review of the existing literature and prohibited us from performing meta-analyses.

Objective evaluation of smile outcome after facial reanimation surgery remains challenging. Quantification of outcomes is inconsistent because of the lack of a standardized outcome scoring system for facial reanimation. Several objective measuring systems have been proposed, but no single system has been widely adopted. To advance the field of facial reanimation, it is imperative to compare outcomes uniformly. To achieve this, a system should be simple, objective, and reproducible; exhibit strong inter- and intrarater correlation; and be able to evaluate surgical outcomes in a clinical setting but also be suitable for research purposes (Bray et al., 2010; Niziol et al., 2015). Objective measurements will objectify results, but they do not necessary provide meaningful information about the quality of a reanimated smile. Indeed, subjective evaluation can sometimes provide more information about outcomes than simply objective data. Although it remains imperative to collect quantifiable data for objective comparisons, subjective scales should definitely be included, and the differences between “automatic” and “emotional” spontaneous smiles should be taken into account and noted, as it seems that “emotional” smiles evoked by muscles innervated by the masseteric muscle are relatively rare. It is also preferable to express commissural excursion as a percentage compared to the healthy side, to avoid interpersonal smile differences. Future research regarding facial reanimation surgery outcomes should aim to exhibit these features: randomized clinical trial design, standardized surgical protocols for the most suitable surgical technique, standardized measuring scale, standardized physical therapy postoperatively, and follow-up for at least 1 year after the last surgical procedure.

CONCLUSION

Facial reanimation is a challenging branch of reconstructive surgery. New concepts and innovations attempt to achieve outcomes that are both natural and symmetric (Biglioli et al., 2012). There are currently no RCTs or CCTs available in the literature regarding facial reanimation surgery. Patients operated on by lengthening temporalis myoplasty reach a lesser extent of smiling in most studies, except those from Labbé himself, with controversial evidence of spontaneity. Thus, there is no real evidence to suggest that LTM might be a better option than gracilis free muscle transfer. The heterogeneity of the retrieved publications and the wide variety of outcome variables posed serious restrictions on this systematic review. Until stronger evidence becomes available, free muscle transfer remains the gold standard for facial reanimation. However, LTM according to Labbé seems to be a reasonable option in some cases because it is less extensive, does not require muscle harvesting, results in very high rates of spontaneous smiling, and does not require microvascular anastomosis, and therefore it should be considered more often as a suitable alternative (Veyssière et al., 2015).

It is not possible to impose a single technique for use in all patients undergoing facial reanimation surgery. Every patient should be evaluated separately, and his or her wishes should be taken into account when deciding which technique is suitable. Our results suggest that LTM is a good alternative to free muscle flap, which deserves to be considered in many more cases than at present.

Conflict of interest

There are no conflicts of interest to declare. The authors have no financial interest regarding the content of this article.

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Table 1. Patient demographics

Author, year of publication	Age range	Mean age	Mean follow-up period	N	Cause of facial paralysis							
					Tumor resection	Bell's palsy	Traumatic	Iatrogenic	Other	Idiopathic	Moebius	Other
Ferreira & Marques de Faria, 2002	NM	NM	NM	26				NM				
Ylä-Kotol et al., 2004	7-65 years	40	8,5 years	11				NM				
Terzis & Olivares, 2009	17-53 years	30.71	8,4 years	10	2		4				1	3
Manktelow et al., 2006	16-61 years	34.4	4,7 years	31				NS				
Bae et al., 2006	NM	10	NM	20	15		5					
	NM	8.8	NM	32							16	
Faria et al., 2007	5-63 years	28.6	5,1 years	58				NM				
	9-58 years	26.5	1,8 years	22								
Bianchi et al., 2010	7-60 years	20.5		15				1			14	
Hontanilla et al., 2013	NM	42.4	38,4 months	20	9	1	3	2	2			3
	NM	40.7	33,2 months	27	19		4	2	2			
Bhama et Al., 2014	NS	NS	NS	78				NS				
Cardenas-Mejia et al., 2015	13-60 years	37.6	NM	9	5		2			2		
Sforza et al., 2015	9-75 years	41	17 months	13				12				1
Biglioli et al., 2012	46-53 years	49.5	NM	6	4		1			1		
Labbé & Huault, 2000	11-71 years	43.6	NM	10	5		2					3
Hayashi et al., 2014	41-72 years	57.8	32,8 months	5	4							
	7-57	23.8	NM	34			11				9	14

Veyssiere & Labbe & Huault, 2014	years				
Gousheh et al., 2011	3-72 years	25.7	NM	505 4	NS

Abbreviations: NM= not mentioned, NS= not specified

Table 2. Characteristics of the surgical intervention

Author, publication year	Surgical technique	N	Time between 2 stages	Mean period till movement	Complications, n	
Ferreira & Marques de Faria, 2002	Gracilis flap + CFNG	26	6- 12 months	6-12 months	not mentioned	
Ylä-Kotol et al., 2004	Gracilis flap + CFNG	11	9-12 months	6- 8 months	infection	not specified
					hematoma	not specified
Terzis & Olivares, 2009	Gracilis flap + CFNG	10	6- 24 months	not mentioned	no function	1
					flap loss after VT	1
Manktelow et al., 2006	Gracilis flap + MMN	31	/ (one stage)	not mentioned		
Bae et al., 2006	Gracilis flap + CFNG	20	9-15 months	not mentioned	not mentioned	
	Gacilis flap + MMN	32	/ (one stage)			
Faria et al., 2007	Gracilis flap + CFNG	58	not mentioned	6-15 (mean 11,1) months	hematoma	4
	Gacilis flap + MMN	22	/ (one stage)	3-6 (mean 3,7) months	salivary fistula	2
Bianchi et al., 2010	Gracilis flap + CFNG	7	not mentioned	3,5- 6 months	hypertrophic scar	1
	Gracilis flap + MMN	8	/ (one stage)	not mentioned	dyskinesia	1
Hontanilla et al., 2013	Gracilis flap + CFNG	20	mean of 239 days	not mentioned		
	Gracilis flap + MMN	27	/ (one stage)			
Bhama et Al., 2014	Gracilis flap + CFNG	35	not mentioned	not mentioned		
	Gracilis flap + MMN	43	/ (one stage)			
Cardenas-Mejia et al., 2015	Gracilis flap + CFNG + MMN	9	7-12 weeks	12-15 weeks		
Sforza et al., 2015	Gracilis flap + CFNG + MMN	13	/ (one stage)	not mentioned		
Biglioli et al., 2012	Gracilis flap + CFNG + MMN	6	/ (one stage)	3,8 months		

Labbé & Huault, 2000	TLM	10	/ (one stage)	not mentioned	infection	1
Hayashi et al., 2014	TLM	5	/ (one stage)	3-4 months	dimple formation	2
					reduced mouth opening (temporary)	4
					salivary fistula	1
Veyssiere & Labbe & Huault, 2014	TLM	34	/ (one stage)		infection	1
Gousheh et al., 2011	Gracilis flap + CFNG	505				
	TLM	4	/ (one stage)			

Abbreviations: CFNG= cross-facial nerve graft, MMN= masseter motor nerve, VT= venous trombosis, TML= temporalis lengthening myoplasty

Table 3. Included studies and evaluation of the surgical outcome

Author, year of publication	Study design	Surgical technique	N patients	Outcome measurements		Results			
Ferreira & Marques de Faria, 2002	retrospective	gracilis flap + CFNG	26	subjective evaluation		excellent	good	fair	
					patient	13	7	4	
					surgeon	11	11	3	
					observer	7	9	7	
			26	objective evaluation				static	dy
					preoperative		Lowest	76°	
							Highest	98°	
							average	79°	6
							SD	5,9°	
					postoperative		Lowest	81°	
							Highest	90°	
							average	84°	7
							SD	4,6°	
			26	Van Swearingen and Brach				FF	
					preoperative		Lowest	31,2	
							Highest	93,7	
							average	58,5	
							SD	21,6	
					postoperative		Lowest	68,7	
							Highest	100	
							average	86,5	
							SD	11,2	
Ylä-Kotol et al., 2004	retrospective	gracilis flap + CFNG	11	House grading		not specified			
Terzis & Olivares, 2009	retrospective	gracilis flap + CFNG	10	Terzis and Noah Functional and Aesthetic Grading System for Smile		not specified			
				Needle Electromyography Interpretations		not specified			
Manktelow et al., 2006	retrospective	gracilis flap + MMN		FaceMS			commissure movement		mi
							distance (mm)	direction (°)	dista (mm
			31			All muscles	13 +/- 4,7	46 +/- 15	8,
			24			bilateral	13,5 +/- 5	44 +/- 15	8,7
			8			unilateral	11,2+/- 3,6	54 +/- 12	7
			8			normal	13,1 +/- 4,6	51 +/- 10	9,8
						Values mean +/- SD			
							(very)good	OK (%)	No

							(%)		
				Questionaire		smile in mirror	74	15	
						smile on photograph	48	37	
Bae et al., 2006	retrospective					No.	Mean (mm)	SD	
		gracilis flap + CFNG	20	Extend of commissure	normal side	20	15,2	4,19	
					operated side	20	7,9	3,87	
		gracilis flap + MMN	32	movement with smile	left	16	13,8	4,96	
					right	16	14,6	3,7	
Faria et al., 2007				absent	poor	fair	good	excellent	vo
	retrospective	gracilis flap + CFNG	58	4	10	24	0	7	54
		gracilis flap + MMN	22	0	0	3	6	13	22
Bianchi et al., 2010	retrospective	gracilis flap + CFNG	7	FaceMS					
				Questionnaire		Not mentioned			
		gracilis flap + MMN	8						
Hontanilla et al., 2013	retrospective					mean commisural displacement (mm)		Commissure Con Velocity (mm/s)	
						healthy	reanimated	healthy	rean
		gracilis flap + CFNG	20			8,4 +/- 3,1	5,1 +/- 2,6	33,3 +/- 11,9	23
		gracilis flap + MMN	27			9,1 +/- 3,4	7,7 +/- 2,8	31,3 +/- 15,1	31
Bhama et Al., 2014	retrospective				affected side		symmetry (angle)		
					excursion	angle	rest	smile	
		gracilis flap + CFNG	35	FACE-Gram	6,5	7,1	4,5	4,8	
		gracilis flap + MM	43	FACE-Gram	8,7	5,2	4,7	4,3	
Cardenas-Mejia et al., 2015	retrospective	gracilis flap + CFNG + MMN	9	Terzis' Functional and		poor	fair	moderate	g
				Aesthetic Grading	preoperatively	7	2	0	

				System for Smile	postoperatively	0	0	1	
Sforza et al., 2015	retrospective	gracilis flap + CFNG + MMN	13	SMART system		Maximum smile	Maximum smile	Maximum smile	Spo
						before	after	clenching after	b
					Healthy side (mm)	41,7 +/- 9,7	32,4 +/- 8,8	35,9 +/- 11,3	46
					Paretic side (mm)	21,9 +/- 7,3	23,1 +/- 7,9	29,9 +/- 9,6	28
					Ratio (%)	52,18 +/- 10,69	74,95 +/- 30,72	91,18 +/- 41,41	62 1
					Asymmetry index (%)	32,27 +/- 8,74	17,15 +/- 18,22	8,48 +/- 22,13	23
Biglioli et al., 2012	retrospective	gracilis flap + CFNG + MMN	6	Terzis and Noah Functional and Aesthetic Grading System for Smile		poor	fair	moderate	g
					preoperatively				
					postoperatively	0	0	1	
Labbé & Huault, 2000	retrospective	TLM	10	Subjective evaluation by third person			poor	average	g
					static	early	0	0	
						late	0	1	
					dynamic	early	0	1	
						late	0	4	
Hayashi et al., 2014	retrospective	TLM	5	Subjective evaluation by patient		Not mentioned			
Veyssiere & Labbe & Huault, 2014	retrospective	TLM	34	Subjective evaluation by patient and surgeon		Not mentioned			
Gousheh et al., 2011	retrospective			commisural movement			Bad	satisfactory	g
		gracilis flap + CFNG	505				10	40	
		TLM	4				0	0	

Abbreviations: CFNF= cross-facial nerve graft, MMN= masseter motor nerve, SD= Standard Deviation, PF= physical function, SW= social/well being, TML= temporalis lengthening myoplasty

Table 4. Terzis and Noah facial grading system

Grade	Description	Score
Excellent	Symmetrical smile with teeth showing, full contraction	V
Good	Symmetry, nearly full contraction	IV
Moderate	Moderate symmetry, moderate contraction, mass movement	III
Fair	No symmetry, bulk, minimal contraction	II
Poor	Deformity, no contraction	I

Table 5. Needle electromyography interpretations

Number of motor unit potentials	Contraction	Electrogenesis
3	Full (80-100%)	3+, full, complete interference pattern (+++)
2	Moderate (40-70%)	2+, moderate, incomplete interference pattern (++)
1	Poor (10-30%)	1+ (poor (+/-)
0	None	0, none (-)

Table 6. Grading system (nonvalidated) based on shape and intensity

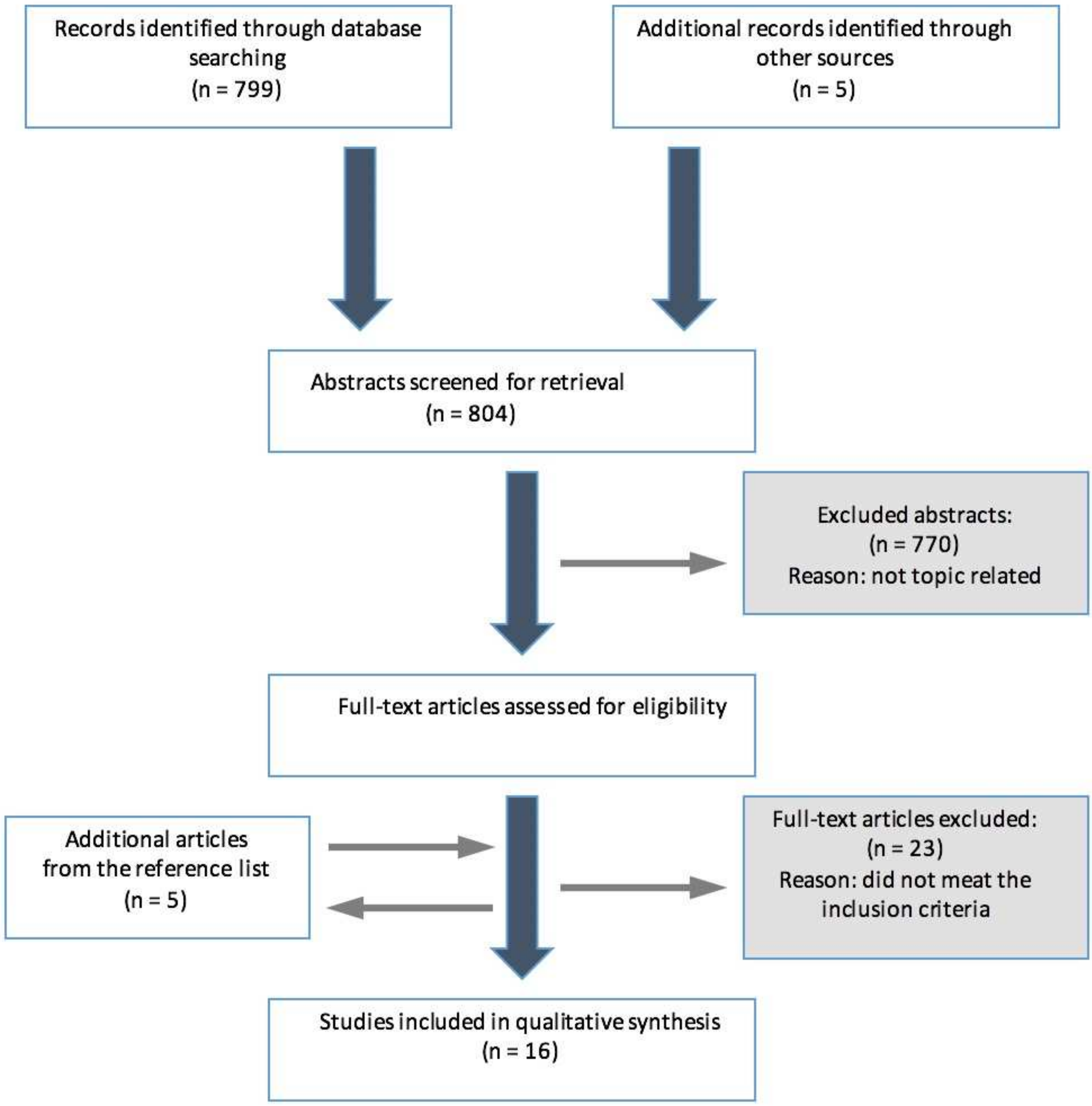
Absence of movement
Poor: muscle contraction visible without movement of the modiolus
Fair: movement of the modiolus present but not enough to form a smile
Good: adequate smile shape but asymmetric with the nonparalyzed side
Excellent: symmetrical smile (shape and intensity)

Table 7. Gousheh et al. (2011) classification system

Final outcome assessment	Oral commissure symmetry at rest	Maximal lateral movement of commissure on the paralyzed side
Excellent	Nearly full symmetric	Equal or more than 2 cm
Good	Mild asymmetric	1.5–2 cm
Satisfactory	Moderate asymmetric	1-1.5 cm
Failed	Severe asymmetric	Less than 1 cm

Table 8. Overview of the characteristics of each technique

		Gracilis flap		Temporal lengthening myoplasty
	CFNG	V3	Double	
Smile	spontaneous	conscious	both	spontaneous (majority)
Smile intensitity	weak	strong	both	strong
Physiotherapy	average intense	very intense	average intense	Very intense
No. of surgeries	2	1	1	1
Nerve graft	sural nerve	/	Sural nerve	/
Anastomosis	2	1	1 + 2	none
Recuperation	long	shorter	shorter	short


Records identified through database searching
(n = 799)
Additional records identified through other sources
(n = 5)
Abstracts screened for retrieval
(n = 804)
Excluded abstracts:
(n = 770)
Reason: not topic related
Full-text articles assessed for eligibility
Additional articles from the reference list
(n = 5)
Full-text articles excluded:
(n = 23)
Reason: did not meat the inclusion criteria
Studies included in qualitative synthesis
(n = 16)